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Article · January 2018

DOI: 10.1016/j.jaip.2017.12.032

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Original Article

Errors in the Use of Inhalers by Health Care Professionals: A Systematic Review

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What is already known about this topic? Health care professionals who care for patients with chronic respiratory diseases have insufficient knowledge about the correct use of inhaler devices.

What does this article add to our knowledge? This is the first systematic review to show that a substantial majority of health care professionals do not use the main inhaler types properly. Surprisingly, inhaler technique skills among professionals have worsened in recent years despite extensive training efforts.

How does this study impact current management guidelines? These results highlight the urgent need to design efficient strategies to improve the training of health care professionals in the appropriate use of inhalers.

BACKGROUND: Inefficient inhaler technique (IT) compromises the optimal delivery of medication. However, the IT knowledge of health care professionals (HCPs) has received scant attention.

OBJECTIVE: The objective of this study was to perform a systematic review of published reports assessing the IT proficiency of HCPs in using pressurized metered dose (pMDI) and dry powder (DPI) inhalers.

METHODS: Studies published between 1975 and 2014 that directly assessed the IT skills of HCPs were selected according to predefined selection criteria.

RESULTS: Data were extracted from 55 studies involving 6,304 HCPs who performed 9,996 tests to demonstrate their IT proficiency. Overall, the IT was considered correct in 15.5% of cases (95% confidence interval [CI], 12-19.3), decreasing over time from 20.5% (95% CI, 14.9-26.8) from the early period (defined as 1975-1995) to 10.8% (95% CI, 7.3-14.8) during the late period (1996-2014). The most common errors in the use of pMDIs were as follows: not breathing out completely before inhalation (75%; 95% CI, 56-90), lack of coordination (64%; 95% CI, 29-92), and postinhalation breath-hold (63%; 95% CI, 52-72). The most common errors using DPI were deficient preparation (89%; 95% CI, 82-95), not breathing out completely before inhalation (79%; 95% CI, 68-87), and no breath-hold (76%; 95% CI, 67-84).

CONCLUSIONS: HCPs demonstrated inadequate knowledge of the proper use of inhalers. The poor understanding of the correct use of these devices may prevent these professionals from being able to adequately assess and teach proper inhalation techniques to their patients. © **2018 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2018;■:■-■)**

Key words: *Pressurized metered dose inhalers; Dry powder inhalers; Administration; Inhalation; Inhalers; Inhaler technique; Health care personnel*

The therapeutic efficacy of inhaled drugs depends to a large extent on the amount of drug deposition on the bronchial tree. A deficient inhalation technique may cause insufficient drug delivery and, thus, therapeutic failure.[1,2] The correct technique depends on the inhaler type, and thus users should receive specific training in the use of the particular device. According to clinical practice guidelines, all patients should be trained in proper inhaler use before receiving a prescription for a new inhaler.[3,4] Guidelines also recommend regular assessment of the patient's inhaler technique (IT) at each clinical visit. However, the available evidence shows that many patients are unable to use their inhalers effectively.[5] Importantly, inadequate IT is common and associated with poor disease control, exacerbations, hospitalizations, and the need for oral corticosteroid and antimicrobials in patients with asthma (adults and children) and chronic obstructive pulmonary disease (COPD).[6-11] Moreover, a lack of competence in inhaler use (unwitting nonadherence behavior patterns) is an important adherence-related barrier,[12] especially among elderly patients.[13]

Incorrect inhaler use can be divided into 3 broad categories: (1) device-related (eg, unintuitive design, difficult-to-use, need for difficult maneuvers to obtain adequate performance), (2)

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No funding was received for this work.
Conflicts of interest: The authors declare that they have no relevant conflicts of interest.
Received for publication September 18, 2017; revised December 15, 2017; accepted for publication December 30, 2017.
Available online ■■

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2213-2198

https://doi.org/10.1016/j.jaip.2017.12.032

Abbreviations used
CI- Confidence interval
COPD- Chronic obstructive pulmonary disease
DPI- Dry powder inhaler
HCP- Health care professional
I^2- Study heterogeneity
IC- Inhalation chamber
IT- Inhaler technique
MeSH- Medical subject heading
pMDI- Pressurized metered-dose inhaler
PRISMA- Preferred Reporting Items for Systematic Reviews and Meta-Analyses

patient-related (eg, motor deficits, cognitive impairment, psychiatric disorders, poor understanding of the critical maneuvers, contrivance), and (3) health care professional (HCP)-related (eg, insufficient knowledge of inhalers, prescription of multiple inhalers, lack of time, deficient doctor-patient communication, failure to regularly check IT).

The quality of the instructions given by HCPs to patients is a key factor that can be improved to reduce inhaler mishandling.[14] However, previous studies have shown that HCPs often have poor knowledge of inhalers and IT.[15-20] To better understand the extent of this problem, a review of the general patterns observed in published studies is needed. The information obtained in such a review could serve as the basis for future recommendations and corrective strategies.

In this context, we performed a systematic review of all studies assessing the IT of HCPs published between January 1975 and December 2014. The aim of this review was to examine: (1) the quality of the IT that HCPs demonstrate to their patients, (2) to identify the most common errors in inhaler use, and (3) to assess changes in IT quality by HCPs over the past 40 years. A secondary objective was to compare the findings of the current review with those obtained in a previous systematic review conducted by our group in which a similar methodology was used to evaluate studies carried out in patients (rather than HCPs) during the same time period.[5]

METHODS

The selection criteria and methods used in this review were similar to those of a recent systematic review conducted by members of our group.[5] See https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=9347 for full details of the protocol.

Study selection and data extraction

Articles assessing the extent and prevalence of incorrect inhaler use by HCPs directly involved in the care of respiratory patients were selected for review. Most HCPs in these studies were pulmonologists and allergists, but other professionals included general practitioners, internal medicine specialists, pediatricians, medical residents, medical students, respiratory therapists, nurses and nursing students, pharmacists, pharmacy students, and pharmacy technicians. Inclusion criteria for the studies were as follows: (1) main study aim—evaluation of inhaler use and IT, and (2) assessment of II based on direct observation of the subject's technique by trained personnel using an inhaler-specific checklist that included all steps. The specific maneuvers that had to be directly observed and assessed[21,22] are described in Table I.

TABLE I. Details of the inhalation maneuver steps for the 3 types of devices

Device	Steps	Maneuvers
Pressurized metered dose inhaler (pMDI)	1.	Preparation: take off the cap, shake, hold inhaler (canister vertical, mouthpiece down, and horizontal)
	2.	Breathe out completely
	3.	Place teeth and lips around the mouthpiece* with the tongue flat under it and fire the device while beginning a slow inhalation
	4.	Inhale slowly and deeply, without stopping
	5.	Hold the breath for 5 to 10 s or as long as possible
pMDI with inhalation chamber (pMDI+IC)	6.	Preparation: take off the cap, shake the inhaler while holding it vertically
	7.	Connect pMDI mouthpiece to the back of the spacer
	8.	Exhale completely (until residual volume)†
	9.	Place the spacer mouthpiece between teeth and close lips around it
	10.	Actuate canister once while inhaling slowly and deeply. Then, hold the breath for 5 to 10 s or as long as possible‡
Dry powder inhaler (DPI)	11.	Preparation: uncap; prime the inhaler according to manufacturer instructions
	12.	Turn away from the inhaler and breathe out completely
	13.	Place teeth and lips around the mouthpiece to form a seal
	14.	Breathe in with one brisk, forceful and deep inhalation
	15.	Hold the breath for 5 to 10 s or as long as possible

The list of steps for the different devices is based on the early descriptions of Dolovich et al[21] and Newman et al[22] and later endorsed by the recommendations of international bodies.[2,23] Step numbers 1 to 5 refer to inhalation technique steps of pMDI; 6 to 10, for pMDI+IC; and 11 to 15, DPI.
*With the pMDI, the open mouth technique was also accepted.
†Step 8 of pMDI+IC could be ignored, particularly in small children and elderly; a single, long deep expiration outside the chamber and long deep inspiration (small chambers) in older children or adults using large chambers were also accepted.
‡At least 5 tidal breaths were also acceptable and, if done, breath holding was then not evaluated.

The electronic database PubMed MEDLINE (U.S. National Library of Medicine, Bethesda, Md) was systematically searched from January 1, 1975, to December 31, 2014. Reports published in English, French, and Spanish languages were considered. The search terms related to inhalers and their use were as follows: *inhaler* (title word) AND *technique* (title word) and *errors* (title word); *inhaler* (title word) AND *education* (title word); *inhaler* (title word) AND *technique* (title word); *spacers* (title word) AND *asthma* (title word); *metered dose inhaler* (Medical Subject Heading [MeSH] term) AND *use* (subheading) OR *dry powder inhaler* (MesH term) AND *use* (subheading) OR *inhalation chambers* (MeSH term) AND *use* (subheading). Using the limit of "other term" the brand names of

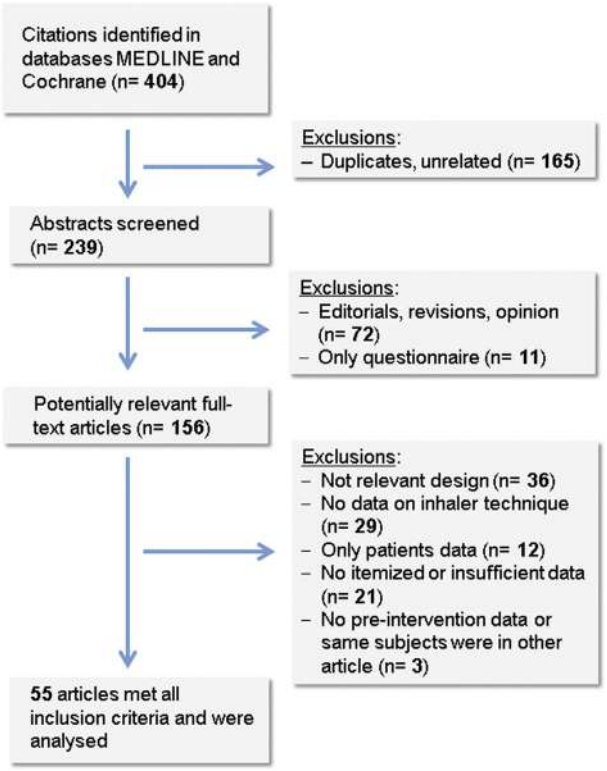

FIGURE 1. Study selection process.

dry powder inhalers (DPIs) were also searched. These included Turbuhaler, Diskhaler, Diskus/Accuhaler, Rotahaler, Novolizer, Cyclohaler/Aerolizer, Handhaler, Clickhaler, Swinghaler, Jethaler, Benosid N, Easyhaler, Elpenhaler, and Nexthaler. All these terms were then combined with the following terms: physicians, house staff, medical students, nurses, nursing students, pharmacists, pharmacy students, respiratory therapists, and health care professionals. The articles thus identified were checked against an annotated bibliography available from the National Electronic Library for Medicines[24] and against the investigators' own files. In addition, the references included in each of the selected articles were reviewed to identify any articles that might have been missed. Papers providing insufficient information about the maneuvers of the IT were excluded. The search results are shown in Figure 1.

Potentially relevant articles were independently screened for eligibility in an unblinded, standardized manner by 2 reviewers (J.G. and J.S.), initially by reading the abstract and then by full text (when necessary) evaluation to determine whether the article met the inclusion criteria. The same 2 reviewers extracted the pertinent information from each included paper: authors and year of publication; setting (country); HCP specialty subgroup, classified as described previously; type of inhaler (pressurized metered-dose inhaler [pMDI], pMDI with inhalation chamber [pMDI+IC], and DPI); number of observed tests of technique using a given inhaler type; percentage of tests presenting the 3 most frequent errors for each inhaler type; and percentage of IT tests classified as correct, acceptable, or poor. The IT was considered correct if the researchers from the original papers considered that all steps had been performed in accordance with recommendations (see Table I), acceptable (or good, but suboptimal) if the researchers thought that only approximately three-quarters of the steps (including all critical steps) had been performed as recommended, or poor when ≤50% of steps had been performed as recommended or when any critical steps were faulty.[21,22,24-26] Critical IT errors[7] for the pMDI were as follows: (1) not holding the inhaler upright (step 1, Table I), (2) exhaling into the mouthpiece (step 2), and, particularly, (3) poor coordination between the start of inhalation and dose actuation (step 3). The critical errors for the DPI were failure to seal the lips around the mouthpiece with the Turbuhaler (step 13 of Table I) and insufficiently fast inhalation (step 14). The total number of individual tests performed for each inhaler type and the total number and type of errors made for those inhalers were recorded and percentages were calculated. Any disagreement between the members of the review team was resolved by discussion with a third reviewer (V.P.).

Outcomes and data synthesis

Study outcomes included all of the following: (1) IT quality, (2) change over time in IT quality, (3) error rates in the various IT steps according to inhaler type, and (4) distribution of the 3 most common errors made for each device type and each HCP subgroup. IT quality was measured as the percentage of HCPs who demonstrated a correct IT. To assess changes in IT quality over time, the study period for the pMDI and pMDI+IC devices was divided into early (from 1975 to 1995) and late (1996 to 2014) periods, whereas the study period for DPIs was divided into early (1990 to 2002) and late (2003 to 2014) periods. Note that recording error reports from these heterogeneous studies were complex because some steps—especially *preparation* (steps 1, 6, and 11 [Table I])—comprised various components that varied according to the inhaler type. Furthermore, some of these components were less important; therefore, when a study reported errors in more than one component of a single step, only the frequency of the most important component was tabulated.

Statistical analysis

Analyses were selected to follow, to the extent possible, the recommendations of the *Cochrane Handbook for Systematic Reviews of Interventions*[25] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[27] Data were recorded in a spreadsheet and analyzed using StatsDirect Statistical Sofware (V3.0.177; http://www.statsdirect.com). The percentage of patients with a correct inhalation technique was calculated by meta-analysis, which determined the overall percentages and those for each inhaler type and HCP subgroup. The precision of the estimates was quantified by 95% confidence intervals (CI) using the approximation of a binomial distribution.[28] Given the expectation that the data would be highly heterogeneous, the random effects model was used for all variables. Potential publication bias was explored by funnel plots and the Egger test.[29] Evidence of asymmetry from the Egger test was considered to be significant at $P < .1$.

RESULTS

The electronic database searches yielded 404 articles on IT by HCPs. After removing duplicates and unrelated articles, articles not contributing new data or that did not evaluate overall technique were also excluded (Figure 1). After the full screening process was completed, a total of 55 articles met all inclusion criteria.[18-20,23,30-81] The selected studies were performed in 18 different countries, distributed as follows: 19 in the USA; 5 each in Canada, the UK, and Spain; 3 each in Australia and Saudi Arabia; 2 each in France, Brazil, and Jordan; and 1 each in Israel,

TABLE II. Characteristics of studies included in the review

Author	Country	Year	Study design*	Type of inhalers†	Number	Type of HCP‡
Frew et al[18]	UK	1984	A	pMDI	96	1, 3, 4
Tal at el[19]	Israel	1987	A	pMDI	50	1
Hanania et al[20]	Canada	1994	A	pMDI, IC, T	90	1, 2, 3
Kelling et al[30]	USA	1983	A	pMDI	55	1, 3
Burton et al[31]	UK	1984	A	S, R	43	1
Mickle et al[32]	USA	1990	A	pMDI	52	4
Felez at el[33]	Spain	1991	A	pMDI	110	1, 3
Taylor et al[34]	UK	1991	A	pMDI	88	3, 4
Guidry et al[35]	USA	1992	A	pMDI	61	1, 2, 3
Mas et al[36]	USA	1992	A	pMDI	52	1
O'Connell et al[37]	USA	1992	A	pMDI	56	3
Interiano et al[38]	USA	1993	A	pMDI	170	1, 3
Riduan et al[39]	Malaysia	1993	A	pMDI	41	4
Self et al[40]	USA	1993	A	IC	23	3
Kesten et al[41]	Canada	1993	A	pMDI, IC, T	45	4
Del Río Navarro et al[42]	Mexico	1994	A	pMDI	100	1
Kelcher et al[43]	Canada	1994	A	pMDI, D, T, R, S	23	1
Amirav et al[44]	USA	1995	C	pMDI, IC	50	1
Jones et al[45]	USA	1995	A	pMDI	185	1, 3
Benjaponpitak et al[46]	Thailand	1996	A	IC	127	1
Rebuck et al[47]	Canada	1996	A	pMDI, IC	52	1
Resnick et al[48]	USA	1996	A	pMDI	38	1
O'Donnell et al[49]	UK	1997	A	pMDI	50	1, 3
Plaza et al[50]	Spain	1997	A	T	118	1, 3
Tsang et al[51]	Hong Kong	1997	A	pMDI	100	1
Plaza et al[52]	Spain	1998	E	pMDI	894	1, 3
Chafin et al[53]	USA	2000	A	pMDI	22	1
Chafin et al[54]	USA	2000	A	IC	83	4
Madueño Caro et al[55]	Spain	2000	A	pMDI, IC, T, D	87	1
Hernán Sotomayor et al[56]	Chile	2001	A	pMDI	60	1, 3
Chopra et al[57]	USA	2002	A	pMDI	50	1, 2, 3, 4
Barbosa Muniz et al[58]	Brazil	2003	A	pMDI, IC, DPI	56	1
Lee-Wong et al[59]	USA	2003	A	pMDI, IC	56	1
Casset et al[60]	France	2004	A	pMDI, T, IC	173	4
Iheagwara et al[61]	USA	2005	A	IC	122	1, 3
Owayed et al[62]	Kuwait	2006	A	pMDI	71	1
Scarpaci et al[63]	USA	2007	A	pMDI, IC	47	3
Schammel et al[64]	USA	2007	B	pMDI	38	4
Stelmach et al[65]	Brazil	2007	A	pMDI	239	1
Díaz-López et al[66]	Spain	2008	A	IC	144	3
Basheti et al[67]	Australia	2009	C	T, D,	31	4
Kim et al[68]	South Korea	2009	E	pMDI, D, T	142	1
Toumas et al[69]	Australia	2009	F	T	236	4
Baverstock et al[70]	UK	2010	A	pMDI	150	1, 3, 4
Basheti et al[71]	Australia	2011	A	T, D	73	4
Dominelli et al[72]	Canada	2012	A	pMDI	30	1
Osman et al[73]	Saudi Arabia	2012	A	pMDI, IC	300	4
Khan et al[74]	Saudi Arabia	2013	A	pMDI	71	4
Basheti et al[75]	Jordan	2014	D, F	T, D	31	1, 2, 3, 4
Casset et al[76]	France	2014	A	pMDI, IC, T	86	4
De Tratto et al[23]	USA	2014	A	pMDI, D	100	3
Gemicioglu et al[78]	Turkey	2014	A	pMDI, A, D, T	527	4

(continued)

TABLE II. *(Continued)*

Author	Country	Year	Study design*	Type of inhalers†	Number	Type of HCP‡
Reznik et al[79]	USA	2014	A	IC	169	3
Basheti et al[80]	Jordan	2014	A	pMDI, D, T	109	4
Adnan et al[81]	Saudi Arabia	2015	A	pMDI	96	4

*A, Cross-sectional observational; *B*, cross-sectional randomized observational; *C*, randomized controlled; *D*, single-blind repeated measures; *E*, cross-sectional multicentric observational; *F*, repeated measures parallel group design.
†*pMDI*, Pressurized metered dose inhaler; *IC*, inhalation chamber; *DPI*, inespecific dry powder inhaler; *A*, Aerolizer; *D*, Diskus; *T*, Turbuhaler; *S*, Spinhaler; *R*, Rotahaler.
‡HCP (health care professional): 1, physicians; 2, respiratory therapists; 3, nurses; and 4, pharmacists.

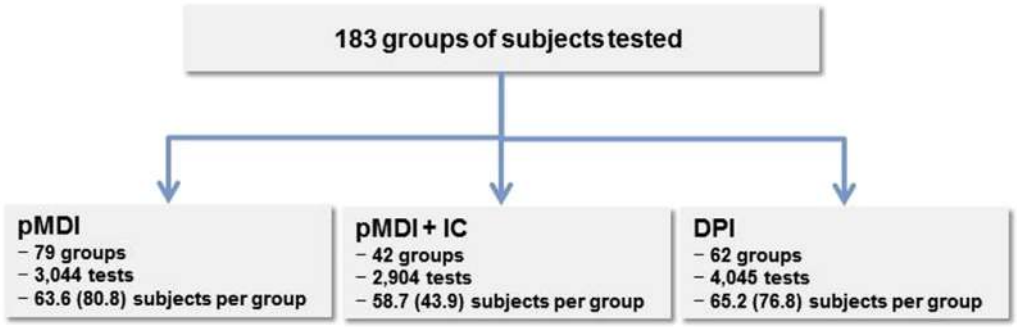

FIGURE 2. Distribution of studies and tests according to inhaler type. *pMDI*, Pressurized metered-dose inhaler; *IC*, inhalation chamber; *DPI*, dry powder inhaler.

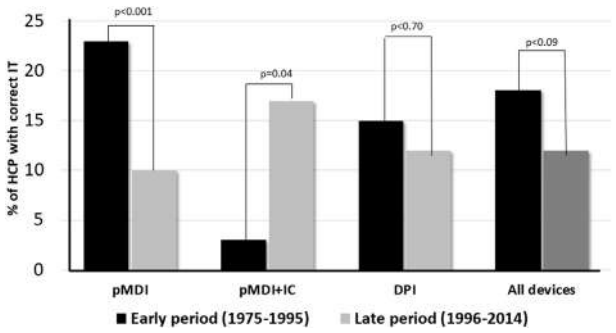

FIGURE 3. Percentage of the correct inhalation technique of the health care professionals over time for all devices separately and as a group. For a dry powder inhaler, the early period was from 1990 to 2002 and the late period was from 2003 to 2014.

Turkey, Mexico, Chile, Kuwait, South Korea, Hong Kong, Thailand, and Malaysia. Although the inhalation procedure protocol checklists were not uniform across studies, all of the checklists included the steps specified in Table I and each error was quantified by frequency in each sample. The general characteristics of the studies included in the review are shown in Table II.

The 55 selected articles[18-20,23,30-81] included data on 6,304 HCPs distributed as follows: pulmonologists and allergists, 377; other physicians (general practitioners, internal medicine specialists, and pediatricians), 2,290; medical residents, 763; medical students, 319; respiratory therapists, 50; nurses, 404; nursing students, 335; pharmacists, 1,402; pharmacy students, 327; and pharmacy technicians, 37. A total of 9,993 tests of the IT were performed. Note that the number of tests was greater than the number of HCPs because in some studies the subjects were tested with more than 1 device. Data were available for 183 groups of subjects, of varying sizes, tested with a single device (Figure 2).

The pMDI was tested in 79 (47.9%) groups, with a total of 3044 tests and a mean (standard deviation) of 63.6 (80.8) subjects per group (range, 10-466 subjects).

There were 19 studies[20,40-44,46,47,53-55,58-61,63,66,73,76,79] related to pMDI+IC; 7 of these studies evaluated a single IC model, whereas the remaining studies reported data on 2 or more different IC or spacer devices, resulting in a total of 42 groups for the pMDI+IC data that generated 2,904 tests with a mean of 58.7 (43.9) subjects per group (range, 20-169 subjects). The IT with Aerochamber—the most common IC tested—was evaluated in 12 of the 19 studies; Inspirease and Optichamber were used in 2 studies; and Nebuhaler, Nebuchamber, Volumatic, Babyhaler, and Optihaler were assessed in only 1 study each. In 2 studies, the type of the IC or spacer was not specified.

The DPI was tested in 62 (37.5%) groups, with a total of 4,045 tests and a mean of 65.2 (76.8) subjects per group (range, 10-266 subjects). The most common DPIs were the Turbuhaler (33 groups with 1,962 tests) and the Diskus-Accuhaler (24 groups with 1,433 tests). Less commonly studied DPIs included Diskhaler, Rotahaler, Spinhaler, and, more recently, Aerolizer; the data from these studies were added to the total DPI data. Between the years 1990 and 2002 (defined as the early period for DPI analysis), 17 reports on Turbuhaler (440 tests) and 9 on Diskus (153 tests) were available for analysis. During the later period (2003-2014), there were 16 reports on Turbuhaler (1,522 tests) and 15 on Diskus (1,280 tests).

Only 15.5% (95% CI, 12-19.3) of the HCPs exhibited a correct IT (Egger's test: bias = 4.05807 [95% CI = 3.069174 to 5.046967], $P < .0001$). This percentage decreased over time,

TABLE III. Error rates in the inhalation technique steps according to the type of inhaler

Inhaler type	Step	Pooled mean (%) (95% confidence interval)
pMDI (groups = 79; tests = 3044)	1. Preparation	57 (41-73)
	2. Breathe out completely	75 (56-90)
	3. Coordination	64 (29-92)
	4. Slow deep inspiration	59 (49-68)
	5. Breathe hold	63 (52-72)
pMDI+IC (groups = 42; tests = 2904)	6. Preparation	63 (38-85)
	7. Connect pMDI to spacer	–
	8. Breathe out completely*	62 (43-79)
	9. Place IC between teeth and close lips	63 (55-71)
	10. Actuate canister once	–
DPI (groups = 62; tests = 4045)	11. Preparation	89 (82-95)
	12. Breathe out completely	79 (68-87)
	13. Mouthpiece between teeth and closed lips	59 (29-85)
	14. Forceful and rapid inhalation	69 (41-91)
	15. Breath-hold	76 (67-84)

pMDI, Pressurized metered dose inhaler; *IC*, inhalation chamber; *DPI*, dry powder inhaler.
Step numbers 1 to 5 refer to inhalation technique steps of pMDI; 6 to 10, for pMDI+IC; and 11 to 15, DPI.
*Step 8 of pMDI+IC could be ignored, particularly in small children and elderly; a single, long deep expiration outside the chamber and long deep inspiration (small chambers) or several tidal breaths in older children or adults using large chambers were also accepted.

TABLE IV. The 3 most frequent inhalation technique steps with errors according to the type of inhaler device and health care professional subgroup

	pMDI			pMDI+IC			DPI		
Frequency of the IT error step number	Most frequent	Second	Third	Most frequent	Second	Third	Most frequent	Second	Third
Physicians									
Pulmonologists and allergists (377 subjects)	2 (41.7)	4 (38.9)	3 (25.0)	–	–	–	12 (88)	14 (74)	15 (70)
Primary care physicians (general practitioners, internal medicine specialists, and pediatricians) (2290 subjects)	5 (57.9)	1 (51.0)	2 (33.75)	8 (70)*	7 (50)	6 (20)	11 (86)	13 (80)	12 (56)
Medical residents and medical students (1082 subjects)	1 (85.0)	4 (63.2)	3 (45.9)	7 (86.0)	8 (83.2)*	6 (73.5)	14 (82.9)	11 (75.4)	12 (73.09)
Respiratory therapists (50 subjects)	4 (72.0)	5 (5)	–	8 (27)*	–	–	11 (91.5)	14 (50)	12 (48.0)
Nurses and nursing students (739 subjects)	4 (91.3)	2 (84.3)	5 (81.9)	8 (68.8)	7 (62.3)	10 (55.4)	11 (98.5)	12 (98.0)	14 (75.0)
Pharmacists, pharmacy students, and pharmacy technicians (1766 subjects)	4 (66.5)	5 (64.5)	2 (61.5)	7 (49.0)	6 (43.7)	10 (29.0)	12 (70.4)	15 (67.1)	11 (50.7)

DPI, Dry powder inhaler; *IC*, inhalation chamber; *IT*, inhalation technique; *pMDI*, pressurized metered dose inhaler.
The values in each cell show the step number of the inhalation technique (given in Tables I and III) and in parentheses, the weighted averages of frequencies (in percentages) of each step given in the studies for each subgroup of subjects. Data on errors are shown in decreasing order of frequency.
*Step 8 of pMDI+IC: a single, long deep expiration outside the chamber and long deep inspiration (small chambers) from the chamber, or several tidal breaths within it in older children or adults using large chambers were both accepted.

from 20.5% ([95% CI = 14.9-26.8]; I^2 = 87.2% [95% CI = 83.5% to 89.7%]; Egger: bias $P < .0001$) in the early study period to 10.8% ([95% CI = 7.3-14.8]; I^2 = 87.9% [95% CI = 84.2%-90.3%]; Egger: bias $P < .0001$) in the late study period, which was particularly worse for the tests with pMDI (Figure 3). The IT improved only in the case of pMDI+IC in the late period.

Table III shows the IT errors that occur in the various steps for each inhaler device in the overall study population of HCPs, with Table IV showing the results for the various HCP subgroups. Overall, DPI devices presented the highest error rates (Table III). The most frequent error using pMDI was observed in step 2 (*breathe out completely*) (75% of errors), followed by a critical error in step 3 (*coordination*) (64%). For DPIs, the most common errors were seen in step 11 (*preparation*) (89%), and a critical error was seen in step 14 (*forceful rapid inhalation*) (69%). The analysis of error distribution by the HCP subgroup (Table IV) revealed no consistent pattern in terms of the steps involved nor in error rates for those steps; however, frequencies were all high or very high. The highest error rates were observed in steps 11 (*preparation*) and 12 (*breathe out completely*), particularly among nurses and respiratory therapists.

DISCUSSION

This systematic review shows that a majority of HCPs involved in caring for patients with respiratory diseases exhibited poor knowledge of the inhalation technique for the main inhalers they prescribe, administer, or supervise. This is a clinically relevant deficiency. Moreover, the rate at which IT was correctly performed decreased considerably in the later years of the study period. Two of the most common IT errors observed in pMDI and DPI, respectively, were lack of coordination (step 3) and forceful rapid inhalation, both of which were labeled "critical" errors by Price et al in the CRITIKAL Study[82] due to their association with uncontrolled asthma and/or increased rates of exacerbations.

Unexpectedly, the results among HCPs were substantially worse than those reported by Sanchis et al[5] in a similar systematic review performed to assess inhaler use by patients. That study reviewed data from 54,354 patients who performed 59,584 observed IT tests. In the present study, we found that HCPs correctly performed IT only half as often as patients did (15.5% vs 31%, respectively); moreover, the mean IT error rates involving the various steps for the pMDI, pMDI+IC, and DPI devices were notably higher among HCPs and similar to the rates that would be expected from a treatment-naive subject using an inhaler for the first time. Error rates among HCPs for coordination and in full expiration before inhalation with pMDI devices were 64% and 75%, respectively, versus 45% and 48% in patients. For DPIs, the comparative error rates between HCPs and patients[5] were, respectively, 89% versus 29% for preparation, 79% versus 46% for full expiration, and 76% versus 37% for breath-hold. In the patient study by Sanchis et al,[5] the overall prevalence of poor technique was 31%, with no significant differences over the 39-year study period. By contrast, in the present study, we found that the IT was poor in 70% of HCPs, increasing from 48% in the early study period to 80% in the late study period.

"Poor inhaler technique may be perpetuated by clinical staff" was the prophetic title of Frew and MacFarlane's paper in 1984.[18] More than 30 years later, the discouraging results obtained in the present systematic review probably reflect the scarce interest that some HCPs have in mastering IT. Some HCPs may believe that these skills are less relevant to their professional competence than other theoretically more complex and sophisticated aspects of treatment. It appears that many physicians often simply prescribe inhaler therapy, taking for granted that the patient will be able to administer it properly; regrettably, patients are often unaware that the efficacy of inhaler therapy depends on a proper technique. Patient training and education in the use of inhalers is an essential part of the tasks of HCPs involved in the care of chronic respiratory patients, including physicians, respiratory therapists, nurses, and pharmacists. The important role of HCPs in this area has been repeatedly emphasized in the medical literature practically since the first inhalers became available. A recent systematic review of 39 studies comprising 56 educational intervention groups on IT in patients with asthma and COPD showed that the interventions are effective in the short-term (average follow-up: 5 months), with favorable clinical outcomes (lung function, symptoms, health care utilization, quality of life) for the intervention group in most studies.[14]

Our findings regarding the high and increasing error rate in IT by HCPs suggest that the extensive efforts aimed at training HCPs and improving their understanding about the correct use of inhalers have either not been effective or the recommendations have largely been ignored. Novel educational strategies are urgently needed to remedy this situation. In this regard, a positive aspect of our results, which show the most common IT errors according to the specific steps for each device and by the HCP group, could probably help to develop training programs tailored to specific HCP subgroups. It is likely that specific and repeated—a key element—educational programs addressed to HCPs according to their needs could improve IT among those professionals, thus leading to greater success in instructing patients in proper inhaler use.[14] Importantly, the use of brief, repeated training programs has been shown to improve clinical outcomes among patients with asthma.[83] On the other hand, technological advances could also help to improve correct inhaler use, as evidenced by the recent introduction of new DPIs that have an easy 3-step process. In the future, a new generation of electronic inhalers designed to facilitate correct IT will likely improve the proper use of these devices among both HCPs and patients.

The heterogeneity of the studies in this review, in terms of population samples, methods, and types of errors, represents a limitation of our study. Also, given the inclusion of nonrandomized studies with a wide range of study designs (observational, descriptive, prospective, and cross-sectional studies, and surveys), we were not able to fully apply the instruments recommended by PRISMA[27] or the Cochrane Group[26] to assess the risk of bias in systematic reviews and meta-analyses of randomized controlled trials. In addition, this review was based on articles retrieved only from the MEDLINE PubMed database; other databases (eg, EMBASE) were not searched. All of these limitations reduce the power of our findings. Nevertheless, we believe that the consistently high error rates among the included studies are a robust, universal, and clinically important finding. The strengths of the present work include the large number of HCPs and observed tests of the IT extracted from 55 articles from a diverse array of countries and health services. We did not have any similar data for comparison because no previous systematic reviews on this topic could be found.

In conclusion, this systematic review shows that a substantial proportion of HCPs with direct responsibility for the management of patients with respiratory diseases have insufficient knowledge of the correct use of inhalers. This poor knowledge may prevent these professionals from effectively teaching and assessing proper inhalation techniques to patients. Our findings suggest that the educational strategies currently used to improve the correct use of inhalers by HCPs have either been unsuccessful or simply not applied. For this reason and in view of the magnitude of the problem, new approaches to tackle this important issue should be urgently developed and implemented.

Acknowledgments

We would like to thank Marta Pulido, MD, PhD, and Bradley Londres for their editorial assistance with this manuscript. V. Plaza was responsible for the conception and design of the study, coordination and supervision of all tasks, and writing of

the manuscript; J. Giner was responsible for the search of databases, selection of studies and data extraction, development of the study database, and critical review of the manuscript for intellectual content; G. J. Rodrigo was responsible for the review of included studies, statistical analysis, and critical review of the manuscript for intellectual content; M. B. Dolovich was responsible for the global analysis of the data, interpretation of the findings, and critical review of the manuscript for intellectual content; and J. Sanchis was responsible for the conception and design of the study, development of the protocol, literature search, selection of studies and data extraction, study database, critical review of the manuscript, and the identification and outline of its most relevant findings. All authors have seen and approved the final version of the manuscript.

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